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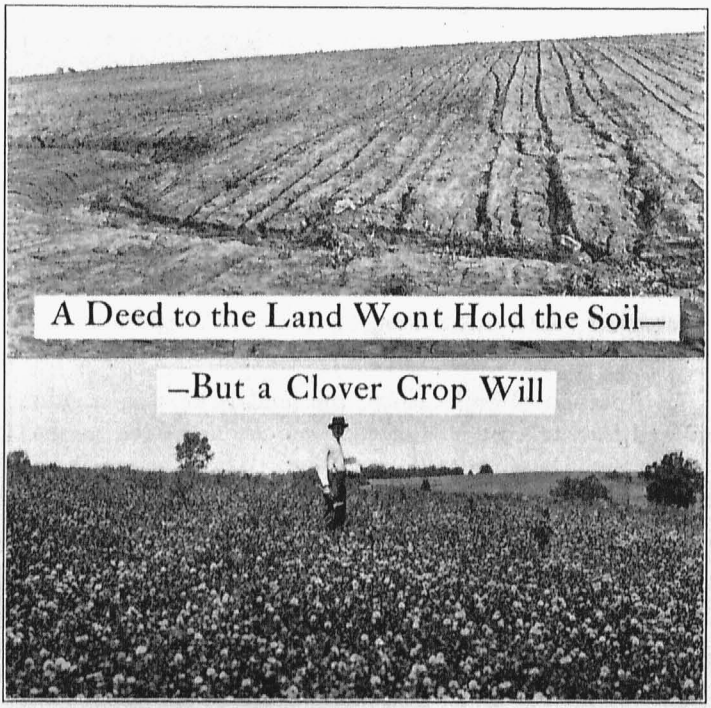
Controlling Surface Erosion of Farm Lands



COLUMBIA, MISSOURI
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HOW TO CONTROL SURFACE EROSION—AND WHY

1. More than 80 per cent of the cultivated land of Missouri is rapidly losing its fertility due to soil erosion.

2. The loss of fertility due to "sheet" erosion is probably greater than the loss due to gullying.

3. Our rolling lands are being depleted more rapidly by erosion than by excessive cropping.

4. The removal of the surface layer takes off the most fertile part of the soil. The most serious losses due to erosion are taking place on our best lands.

5. Soil erosion can be controlled with but little expense, and to the distinct advantage of both farm and farmer.

6. Land with a slope of approximately 15 feet per hundred or over should usually be kept in grass permanently. Very steep or rocky slopes should be utilized for producing timber.

7. Rotation of crops where the land is kept in small grain and hay at least half of the time is one of the most practical methods of controlling erosion. Wherever possible use sod forming legumes instead of cultivated legumes.

8. Cover crops to protect the soil during winter may often be used to advantage.

9. Where possible crops should be planted and cultivated across the slope. Belts of sod across the steep part of the hill will do much to protect the soil on long slopes.

10. Mangum terraces should be built on land that slopes in several directions. These must be carefully maintained.

11. Eroded soils may be rejuvenated by the use of proper crop rotations, manure, fertilizers and lime.

Controlling Surface Erosion of Farm Lands

F. L. Duley

Abstract.—The seriousness of "sheet" or surface soil erosion in depleting the fertility of Missouri soils is shown. The results of carefully controlled experiments are given which show the relative amounts of the surface soil and fertility that have been lost from land having different tillage conditions and different crops. Deep plowing (8 inches) was only slightly more effective than shallow plowing (4 inches) in preventing runoff and erosion. A growing crop on the land, particularly a small grain or sod crop, furnished the most effective means of reducing the erosion. The character of the rainfall largely determined the amount of soil lost. A heavy dashing rain was observed to remove more soil within a few hours than was lost during a whole year when the rainfall was well distributed. The loss of important nutrient elements from the soil through erosion may often be more serious than the loss through the removal of crops. Grass or clover land absorbs much more water than cultivated land. The use of cropping systems that include sod crops like clover or other hays is the most practical means of reducing the surface erosion on rolling lands that must be cultivated a part of the time. Badly eroded soils may be rejuvenated by the use of crop rotations adapted to poor land, provided the proper fertilizer, manure, and lime treatments are applied to the soil.

Most of the worn-out lands of the world are in their present condition because much of the surface soil has washed away, and not because they have been worn out by cropping. Productive soils can be maintained through centuries of farming if serious erosion is prevented. The soils of Missouri have become gradually less fertile during the last one hundred years due in large measure to the excessive cultivation of rolling lands. Many of the most fertile soils in the rolling prairies and timber lands of this state have been kept in corn until the "clay spots" are evident on nearly every hillside. So much soil has been lost from even the more gently rolling parts of the fields that the yields are far below those obtained by our grandfathers who brought the land into cultivation. The erosion of cultivated fields is taking place at such a rate that it is calling for a decided change in our system of soil management. If we are to maintain our acre-yields at a point where crops can be produced at a profit we must make every reasonable effort to reduce the amount of soil fertility that is carried away during heavy rains.

Approximately three-fourths of the area of Missouri is subject to more or less serious erosion. The map (Fig. 2, page 4) shows where these soils are to be found. It will be seen from this map that erosion is serious on many of the most fertile soils of the state. This is particularly true in the rich rolling prairie regions of Central and Northwest Missouri, where owing to the fertility of these soils much of the land is kept in corn a large part of the time. It must be remembered that not all the soils shown within the shaded area erode at

*A complete report of the experimental results obtained over a six-year period, in measuring runoff and the losses from soil erosion has been published by F. L. Duley and M. F. Miller as Missouri Agricultural Experiment Station Research Bulletin 63.

the same rate, but in a general way the map represents the regions where the loss of fertility through erosion is most serious. On the other hand, there is a certain amount of erosion within the less heavily shaded and the unshaded areas, but for the most part these soils are nearly level, or as in the Ozark region, they are largely covered with timber so that erosion cannot be considered a serious problem.

KINDS OF SOIL EROSION

For the most part, on agricultural uplands there are two principal types of soil destruction by water erosion, "gullying" and "sheet erosion". The former is much more noticeable. It may greatly mar the appearance of hillsides and make it difficult to get over the land with tillage implements. Owing to the inconvenience in farming and the fact that small gullies soon increase in size, most farmers attempt to stop the ditches while they are small. This, of course, is a very wise practice which should be universally followed.

Fig. 2.—Map of Missouri showing the parts of the state where erosion is the most destructive to soil fertility. The darker the shading the more serious is the loss from soil erosion.

The other type of water erosion, commonly known as "sheet erosion," consists in the removal of the soil particles from the entire surface of the land without the formation of large gullies. While gullying is much more noticeable, sheet erosion is far more destructive to the fertility of Missouri soils. Most of the material removed in this way is from the dark surface soil which is high in organic matter and rich in plant food material. This bulletin will be devoted almost entirely to methods of controlling this "sheet erosion". However, it should be remembered that as you reduce the sheet erosion much of the trouble from gullies will be controlled incidentally. Furthermore it is seldom that gullies develop without a considerable amount of sheet erosion also taking place.

CAUSES OF SOIL EROSION

Lack of Plant Growth.—There are many factors which tend to increase the erosion from a given soil, but none is more important than the removal of the timber or other vegetative cover from steep slopes. The effect of deforestation has been noticed in practically all sections of the United States. When the timber is removed and erosion progresses for a while it is often difficult to get the tree growth reestablished, due to the impoverished condition of the land.

Many of our rolling prairie soils have likewise been depleted due to the removal of the virgin sod. This has been largely due to the fact that we have not made sufficient attempt in our farming systems to imitate Nature by keeping a crop on the land practically all of the time. Fields broken from the prairies or timber lands have often been kept in corn and other cultivated crops for many years before being put back to sod, which would allow them partially to recuperate from the exhaustive system of continuous cultivation.

Fig. 3.—Erosion in wheat field. Sheet washing may be serious in fields of this sort, and gullies may start by following down the track made by the drill wheel. Wherever possible drilling should be done across the slope rather than with the slope.

Steepness of the Slope.—It is a common observation that steep slopes erode more rapidly than gentle ones. This is due to the fact that as the rate of flow of water is doubled its eroding capacity is increased about sixty times. This means that the amount of erosion will be much more than the difference in the two slopes would indicate. Long slopes also erode more than short ones because of the greater volume of water which collects before the foot of the hill is reached.

Texture of Soil.—Soils which are fairly open and therefore take in water readily, permit less runoff and thus reduce the amount of erosion. Heavy silt loam or clay loam soils absorb water slowly and permit much runoff and erosion during heavy dashing rains. The fine particles are much more easily carried by water than the heavier sand grains. This is the cause of greater loss from the silty and clay loam soils, and is also the cause of the finest particles being carried from the loam and sandy loam soils. The organic matter is light in

weight and is removed quite readily by the runoff water. Owing to the fact that the organic material is rich in plant food elements, the eroded material is more fertile than the soil that is left behind.

Character of Rainfall.— One of the chief reasons why soil erosion is a more serious problem in Missouri than in the states to the north and east of us is because of the large number of heavy rains. Where there is a fairly even distribution of the rainfall the erosion will be much less than where many of the rains come in downpours. The weather records show that during the past 25 years the western part of Missouri has received approximately twice as many torrential rains as the eastern border of the state even though the total rainfall is nearly the same. Rains of 2 inches or more falling in the course of 24 hours

Fig. 4.—Soil erosion on Shelby loam, Worth County, Missouri. Note large gully between the corn rows. All this damage was done by a single heavy rain. It will take years to put back the fertility lost from this soil within a few hours.

are very destructive to rolling lands, particularly those that have been recently worked. Small rains are quickly taken up by the soil, but with heavy rains the proportion of runoff is much greater and as the quantity of runoff water becomes larger its cutting power is vastly increased. Greater precaution should be taken against erosion where the rainfall is unevenly distributed. After a continued wet spell which completely saturates the soil, a quick shower of ½ inch or over may be sufficient to cause considerable erosion, from plowed land.

AMOUNT OF SOIL LOST BY SURFACE EROSION

During the last six years the Missouri Experiment Station has been measuring the amount of soil lost from land by erosion.* This experiment consisted of seven 1-80th acre plots on a gentle slope having a fall of approximately 3.68 ft. per 100 ft. This slope was chosen because it was thought to

*For the complete data secured in this experiment see Research Bulletin 63, Missouri Agricultural Experiment Station.

be not far from, and certainly not greater than, the average slope of cultivated land in Missouri. In this experiment the plots were separated with strips of galvanized iron and concrete tanks were built at the lower end of the slope so that when the rains came the runoff from each plot emptied directly into one of these pits. After each rain the quantity of water running off each plot was measured. The total amount of soil lost was weighed and the amount of dry soil determined by making moisture tests in the laboratory. Each of the seven plots had a special treatment which was designed to represent approximately a common farm condition. Figure 5 shows the condition of these plots.

TREATMENT OF PLOTS

The treatments of the different plots were as follows:

Plot 1.—Land left without crop—not cultivated. Weeds kept down by scraping with hoe or pulling.

Plot 2—Land spaded 4 inches deep in spring and hoed after rains to keep down weeds and prevent crust from forming. This cultivation kept land in condition to absorb the rainfall.

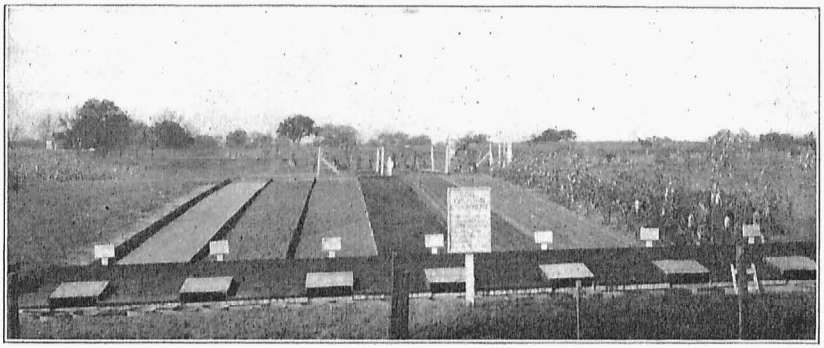


Fig. 5.—General view of plots where measurements have been made on the amounts of soil lost by erosion from land under different conditions.

Plot 3.—Land spaded 8 inches deep in spring and cultivated during the season in the same manner as Plot 2.

Plot 4.—Sod continuously. This land was seeded to bluegrass and kept in sod throughout the entire course of the experiment.

Plot 5.—Wheat annually. Spaded 8 inches deep each year in July and kept cultivated to kill weeds until October when it was planted to wheat.

Plot 6.—Rotation; corn, wheat, clover. Spaded 8 inches deep before corn. Corn harvested in September and land surface cultivated with a hoe before seeding wheat. Clover seeded on wheat in spring.

Plot 7.—Corn annually. Land spaded 8 inches deep each spring. Planted to corn first part of May. Corn cut in October and removed from plot.

RESULTS OF EXPERIMENTS

The results of these experiments have demonstrated very clearly the advantage of certain systems of soil management which prevent the soil from washing. They also show to what degree the water of rains can be absorbed by soils under different conditions of cropping and cultivation.

AMOUNT OF SOIL LOST

Table 1 and figure 2 show the tons of soil that would be lost in six years from an acre of land under the conditions of this experiment.

TABLE 1.—TONS SOIL ERODED PER ACRE IN SIX YEARS

Plot	Treatment	Tons of soil eroded per acre
1	Not cultivated. Weeds pulled.	207.8
2	Spaded in spring 4 in. deep. Cultivated after rains.	247.3
3	Spaded in spring 8 in. deep. Cultivated after rains.	214.2
4	Bluegrass sod	1.69
5	Wheat, annually.	39.9
6	Rotation; Corn, wheat, clover.	13.7
7	Corn, annually.	106.5

The figures in Table 1 show that the loss of soil has been very great from land that does not have a crop. The loss from Plot 2 would be equivalent to hauling off 40 wagon loads of soil from each acre every spring. It is needless to say that such an amount of fertility could not possibly be replaced by the amount of manure produced on the farm. This loss is greater on the plowed land of Plots 2 and 3 than from land that is not plowed and has a hard surface, as in Plot 1. Deep plowing was on the whole slightly better than shallow plowing, but the difference was not great. It would seem from these results that the advantage of deep plowing in preventing erosion is much less than is commonly supposed. That is, while deep plowing absorbs slightly more of the rainfall, the erosion may be very severe during extremely heavy rains.

Plot 4 shows the tremendous advantage of keeping land covered with a good sod, the loss here has been very little indeed. The loss of soil from the plowed land has been more than a hundred times as great as from the grass land. These results would indicate that if land is kept in good sod and no ditches are allowed to start, the loss from soil erosion will be almost negligible.

Plot 5 shows that a small grain crop like wheat protects the soil reasonably well. After the crop gets started the fibrous roots tend to hold the soil and at the same time the tops of the plants afford a certain amount of cover, which very materially reduces the runoff and erosion. The greatest loss of soil from this land has occurred during the months of August and September between the time the land was plowed and the time of seeding the wheat, about the first week in October. This fact would suggest a need for some definite precau-

tions against erosion when plowing rolling land very much in advance of planting. Methods of doing this will be discussed later in this bulletin.

Plot 6 demonstrates very clearly the advantages of crop rotation for the prevention of soil erosion in cultivated soils. A rotation of corn, wheat and clover has allowed less than half as much soil washing as land kept in wheat continually and only about one-seventh as much as land planted to corn each year.

Plot 7 shows that the corn crop affords some protection during the growing season by the fact that the erosion from this plot, which has been in corn

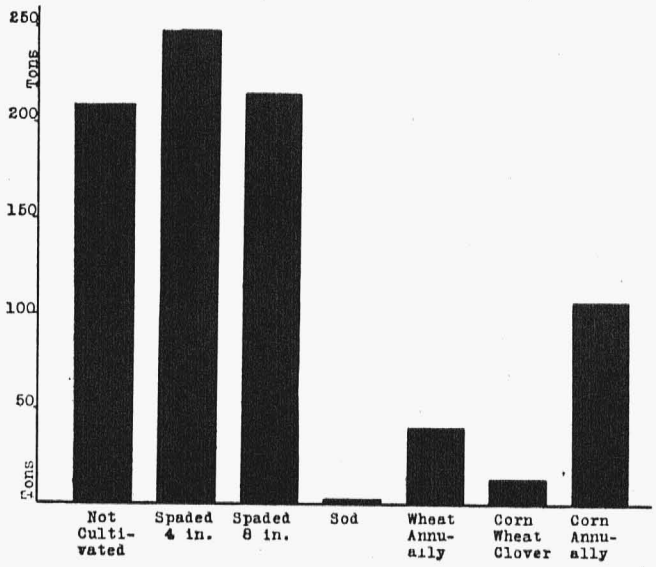


Fig. 6.—Diagram showing comparative amounts of soil eroded from plots with different treatments.

each year, has been less than half the amount lost from Plot 3 which was plowed to the same depth but had no crop. The erosion from corn land, however, is much more severe than from sod, small grain, or rotated land.

It has been further observed in this work that land kept in corn continually erodes much more than land in corn following clover in a rotation. This is due to the fact that land broken from clover sod absorbs more water than land previously in corn and therefore permits a smaller amount of runoff and erosion. The amount of erosion from corn land in the rotation is further decreased because of the fact that this corn makes a much larger growth and consequently takes more water from the soil. This makes it possible for the soil to absorb a greater per cent of the rainfall and thus reduce the amount of runoff.

The significance of these soil losses is brought out in Table 2, which shows the time that would be required to erode the surface 7 inches of soil. The importance of keeping the land covered with a growing crop is shown by a comparison of Plots 2 and 4. The land spaded 4 inches deep has lost soil at

TABLE 2.—NUMBER OF YEARS REQUIRED TO ERODE THE TOP 7 INCHES OF AN ACRE

Plot	Treatment	Years to erode top 7 inches of soil
1	No crop. Uncultivated. Weeds pulled	29
2	No crop. Spaded 4 in. deep in spring. Cultivated after rains	24
3	No crop. Spaded 8 inches deep in spring. Cultivated after rains	28
4	Bluegrass sod	3547
5	Wheat, annually	150
6	Rotation; corn, wheat, clover	437
7	Corn, annually	56

such a rate that the top 7 inches would be removed in about 24 years, while it would require over 3,500 years to remove the surface 7 inches from the sod land. The wheat and rotated land show an enormous saving over the land in corn continually or the uncropped soils. The loss from the corn plot is very significant, since it shows that it may easily be possible to lose practically all the rich surface layer of soil within the course of a generation. That such disastrous losses have actually occurred on many of our soils is shown by the clay points and consequent low yields of crops from many cultivated rolling lands.

TABLE 3.—PER CENT OF THE RAINFALL THAT WAS ABSORBED AND THAT WHICH HAS RUN OFF OF LAND UNDER DIFFERENT SYSTEMS OF MANAGEMENT

Plot	Treatment	Percentage of rainfall absorbed	Percentage of rainfall in runoff
1	No crop. Uncultivated. Weeds pulled	51.08	48.92
2	No crop. Spaded 4 inches deep in spring. Cultivated after rains	68.74	31.26
3	No crop. Spaded 8 inches deep in spring. Cultivated after rains	71.64	28.36
4	Bluegrass sod	88.45	11.55
5	Wheat, annually	74.81	25.19
6	Rotation; corn, wheat, clover	85.86	14.14
7	Corn, annually	72.62	27.38

LOSS OF WATER BY RUNOFF

The plots in this experiment not only showed great differences in the amount of soil removed, but also in the quantity of water absorbed and the amount of runoff. The comparison between the per cent of rainfall absorbed under different conditions is shown in Table 3 and figure 7.

It may be seen from these results that the greatest amount of runoff was from Plot 1 which was not cultivated and was without a crop. On this plot 48.92 per cent or nearly half of the rainfall ran off the surface. At the other extreme is the sod land which absorbed 88.45 per cent of the rainfall thus allowing only a little over one-ninth of the rainfall to run off the surface. It is quite noticeable also that the runoff from each of the cropped plots is less than from Plots 2 and 3 which were kept cultivated but had no plant growth. That is, runoff and erosion usually take place more readily from plowed land than from other land in a crop. Corn and wheat land have allowed about one-fourth

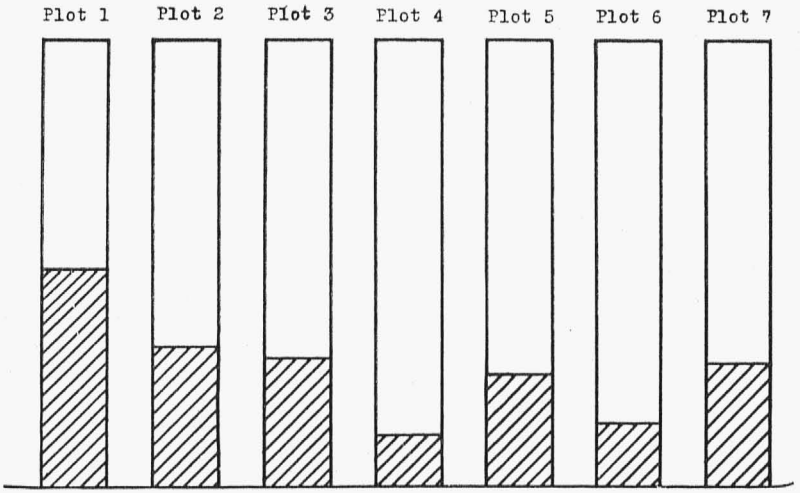


Fig. 7.—Relative amounts of the rainfall absorbed compared with the amount of runoff. The shaded portion represents percentage of runoff. The blank portion of each column represents percentage of rainfall absorbed.

of the rainfall to run off the surface, while the rotated land has lost only about one-seventh of the water in this way. In general, the things which cause a greater absorption of the rainfall also permit less erosion. Hence, if lands are always left in a condition to absorb water the erosion will probably be fairly well controlled. It must be remembered, however, that a smaller amount of soil is lost from cropped land than from plowed land even with the same amount of runoff. Furthermore, in order to get the most benefit from the rainfall it is highly important that the surface be kept in condition to absorb the water that falls. The less water that runs off the surface the greater will be the supply available for the production of crops. Grass land takes in practically all the rainfall except during the very heaviest rains. It is therefore able to make use of more water in the production of vegetative growth than are crops that permit more runoff. When we remember that 300 to 500 pounds of water must be taken up by the plants and evaporated from the leaves in order to produce 1 pound of dry substance, the importance of having the soil in

condition to absorb as much of the rainfall as possible becomes all the more apparent.

It has been found that the surface inches of rainfall absorbed by uncropped land or by land growing a cultivated crop like corn, was practically constant from year to year for a given soil condition, regardless of a wide variation in the annual precipitation. The absorption by sod, wheat and rotated land was more variable.

LOSS OF PLANT FOOD MATERIAL BY EROSION

When we consider the permanent fertility of the soil, the losses of plant food due to erosion must be taken into consideration. It is usually thought that if soils are to be kept up in their productiveness the losses of the more important elements of fertility must be prevented. Much has been said about the loss of plant food due to exhaustive cropping and about the loss of fertility when crops are sold. The present investigation brings out the fact that the loss due to erosion may often exceed the loss due to the removal of average crops. A comparison of Tables 4 and 5 will show the amounts of fertility lost from this land through erosion under various conditions and the amounts that would be lost by the sale of about average grain or hay crops from this same soil. It is evident from these figures that soil erosion must be more seriously considered when we are planning a cropping system which is intended to maintain or increase the total fertility of the soil. In the last part of Table 5 is shown the average amount of fertility in a ton of barnyard manure. This shows that on land kept in corn, several loads of manure will have to be hauled back on each acre in order to replace the fertility lost by erosion. A still further supply would be necessary to put back the fertility lost in the crops sold.

TABLE 4.—POUNDS OF PLANT FOOD ELEMENTS LOST PER ACRE ANNUALLY IN THE ERODED SOIL FROM DIFFERENT PLOTS

Plot	Treatment	Pounds Plant Food Lost Per Acre		
		Nitrogen*	Phosphorus*	Calcium (Lime)‡
1	No crop. Uncultivated. Weeds pulled	98.8	47.4	379.3
2	No crop. Spaded 4 inches in spring. Cultivated after rains	95.4	45.4	337.8
3	No crop. Spaded 8 inches in spring. Cultivated after rains	73.8	33.2	225.6
4	Bluegrass sod	0.5	0.09	0.6
5	Wheat, annually	29.5	10.8	75.9
6	Rotation; corn, wheat, clover	5.9	2.2	41.4
7	Corn, annually	40.3	8.1	103.3

*Average of two years' results.
‡One year's results.

In other words, the absolute maintenance of a soil where much erosion is allowed to go on is an exceedingly difficult matter. Only the very best farmers on the rolling lands in Missouri are keeping up their fertility at the present time. It can be done, however, if proper methods of cropping and soil management are adopted and followed consistently.

TABLE 5.—APPROXIMATE AMOUNTS OF THREE IMPORTANT FERTILIZER CONSTITUENTS REMOVED PER ACRE IN AVERAGE CROPS OF CORN, WHEAT, CLOVER AND THE AMOUNTS RETURNED IN AVERAGE FARM MANURE.

Crop (1 acre)	Pounds of plant food in crops and manure		
	Nitrogen	Phosphorus	Calcium (Lime)
Corn (35 bushels grain)	35	6.3	0.4
Wheat (20 bushels grain)	23	3.0	0.5
Clover hay (2 tons)	80*	10.0	58.4
Manure (1 ton)	10	2.0	--

*Most of the nitrogen in clover hay is taken from the air by the legume bacteria.

PRACTICAL METHODS OF CONTROLLING SURFACE EROSION

The results reported in the foregoing pages of this bulletin demonstrate very clearly some of the fundamental principles concerning erosion control. If these principles are thoughtfully applied and carefully worked into our system of soil management the losses of soil by erosion on the great majority of Missouri farms can be materially reduced.

Some of the factors which affect the amount of erosion, such as the type of soil, the slope of the land, and the amount and character of the rainfall are beyond the control of the farmer. The principal thing the farmer can do to control erosion is to regulate the condition of the surface and the amount and

Fig. 8.—A good stand of red clover is one of the most effective crops for preventing erosion. It has a great advantage because it fits well into Missouri rotations.

kind of vegetative growth. The results given in Table 1 show the enormous saving of soil that may be accomplished by having a growing crop on the land as much of the time as possible. In order to do this it is necessary to carefully plan the cropping system.

CROP ROTATIONS

In planning a rotation for rolling land, crops should be selected that will follow each other in such order that the land will be kept covered with a growing crop practically all of the time. This can be accomplished only by the proper alternation of cultivated crops with small grains, and clover or other hay crops. Table 6 will show how rotations differ in the amount of time that the land is protected with a growing crop. Growing crops are more effective

TABLE 6.—RELATIVE EFFICIENCY OF DIFFERENT CROPPING SYSTEMS IN KEEPING LAND COVERED WITH A GROWING CROP AND THEREBY WELL PROTECTED FROM EROSION.

Rotation	Months in 4 years that land has growing crop	No. of months in 4 years that land is not well protected	Percentage of time land is well protected by crop
Corn, wheat, clover, timothy	46	2	95
Corn, oats, wheat, clover	38	10	79
Corn, soybeans, oats, cowpeas	14	34	29
Corn, continually	20	28	41
Wheat, continually	36	12	75

than dead crops, such as a stalk field, or small grain stubble, because the growing plants remove large quantities of water from the soil. Furthermore, the green crop fills the surface soil with living roots which tend to hold the soil particles and obstruct the flow of water, thus giving it more time to be absorbed.

Fig. 9.—When small grain reaches this height it very thoroughly protects the soil from erosion.

It must be remembered that crops differ greatly in the amount of protection they give while they are on the land. Sod crops are much more efficient than cultivated crops. In the results of experiments reported in Table 1 it may be seen that sod is approximately 20 times as effective as small grain, 60 times as effective as corn and 125 times as effective as plowed land having no crop. From this we may see that for rolling land a sod legume like clover or alfalfa gives much more effective protection from erosion than does a cultivated legume such as soybeans. Furthermore, the clover or sod crop remains on the land for a much longer time than the soybeans.

It may also be seen from Table 6 that a rotation like corn, wheat, clover, timothy would keep the land covered with a growing crop and thus protected from erosion 46 months out of 4 years. The land would have to be plowed but once and would be subject to serious erosion only for the short time in the spring after plowing the timothy sod for corn, and perhaps a few weeks while the corn land is being put into wheat.

A rotation which includes only short season crops affords the poorest protection from erosion. A rotation of corn, soybeans, wheat and cowpeas would keep the land covered less than one-half of the time and none of these crops would be so efficient as a sod crop. Land in corn every year is protected

only about one-third as much of the time as land in wheat continually; furthermore, the protection afforded by corn is not so effective as by wheat.

In many cases, a rotation of short-seasoned crops may be supplemented by cover crops which protect the land during the winter. A crop like rye, or vetch in some cases, may be seeded after corn or soybeans and allowed to stand over winter. It not only furnishes protection to the soil, but gives some winter or early spring pasture and any residue that is left may be plowed under for green manure.

Of course, it must be understood that the rotation must be suited to the type of farming that is being carried on. However, if a farm is located on one of our rolling types of soil the class of livestock kept should be such that "soil protecting rotations" can be used to advantage.

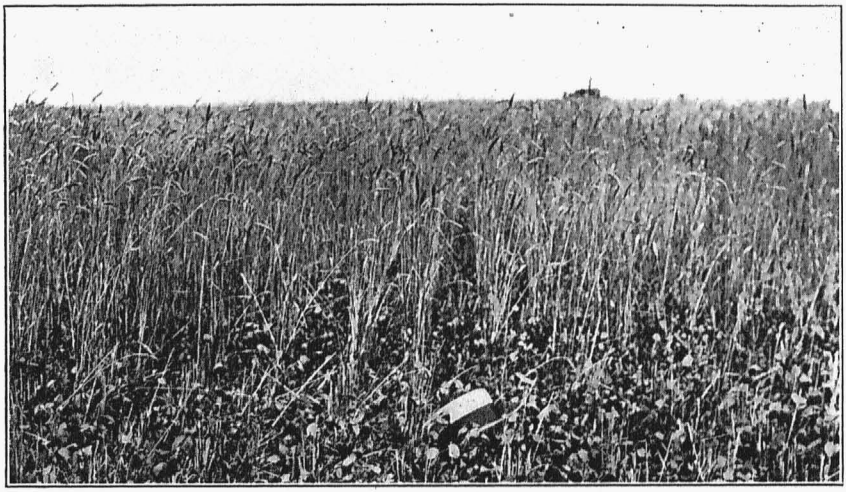


Fig. 10.—When the wheat crop is removed a good growth of clover should be coming on. This insures the soil against serious washing.

There are few other farm practices that will give so many advantages in a farming system as a well planned system of rotation. Furthermore, there is no cost to this practice and in fact the total acre cost of operating the farm will be considerably less than where such a regular system is not followed.

A point has been reached in the agriculture of Missouri where it is imperative that our soils be more thoroughly protected from erosion. To do this nothing is more important than the proper planning of the rotation. However, there are certain other ways of reducing erosion that should not be overlooked in our plans for a complete system of soil management.

USE OF SOD FORMING LEGUMES

Many of the rolling soils in Missouri are rich enough to grow good crops of the sod legumes like alfalfa and sweet or red clover. These sod forming legumes have a great advantage over cultivated legumes like soybeans or cowpeas for holding the soil. The sod legumes cover the entire surface and remain on the

Fig. 11.—A good stand of alfalfa will protect land from erosion through a long period of years and at the same time give a most valuable hay. It thrives well on many types of rolling land in Missouri.

land for a long time. These facts make it desirable in many cases to go to considerable trouble by adding lime or phosphate to put land in shape to produce these sod crops. A strip of alfalfa across the middle of a long slope will do much toward stopping erosion in that field. Furthermore, legumes like alfalfa and sweet clover are among the best for soil improvement, since they gather much nitrogen from the air.

It must also be remembered that red, mammoth, alsike and other clovers are also sod forming legumes, and should be used wherever possible in ordinary Missouri cropping systems. They fit well into the rotation and form an excellent protective covering for the soil.

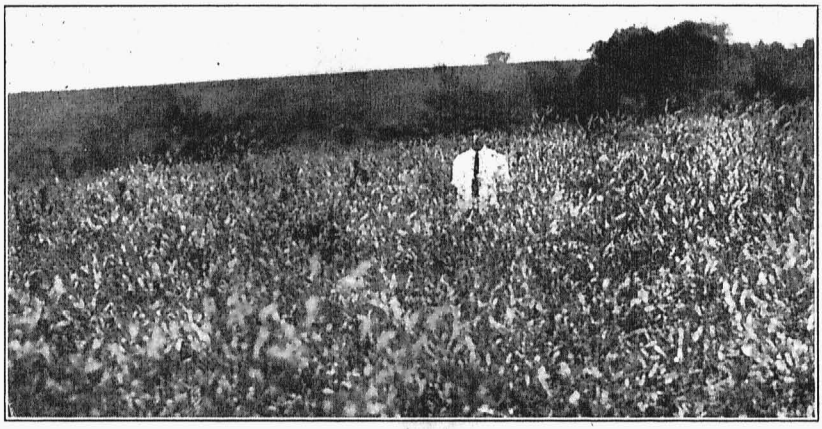


Fig. 12.—Sweet clover is an excellent crop to use on rolling lands which contain abundant lime. It not only holds the soil but gathers nitrogen from the air and thus builds up the fertility of the soil.

PERMANENT PASTURES

It is seldom feasible to attempt to include all of the land in the regular rotation. It is desirable to leave some land on nearly every farm in more or less permanent meadow or pasture. Hillsides which slope more than 15 feet per hundred should seldom be plowed and usually give more profitable returns in the long run if utilized for permanent pasture. Farmers usually recognize this fact and keep such lands in grass. Steep hillsides may be kept in grass for long periods of time with little or no damage from erosion. This is particularly true if care is taken to stop any small gullies that may start. Paths made by livestock may sometimes be the starting point for serious washes. If these are filled at various points with straw or other debris until the path can become resodded, there will be little danger of a gully and practically no loss from sheet erosion from the whole surface. Many soils that are already badly eroded can be built up if put down to grass mixed with clovers and left for a long period of years.

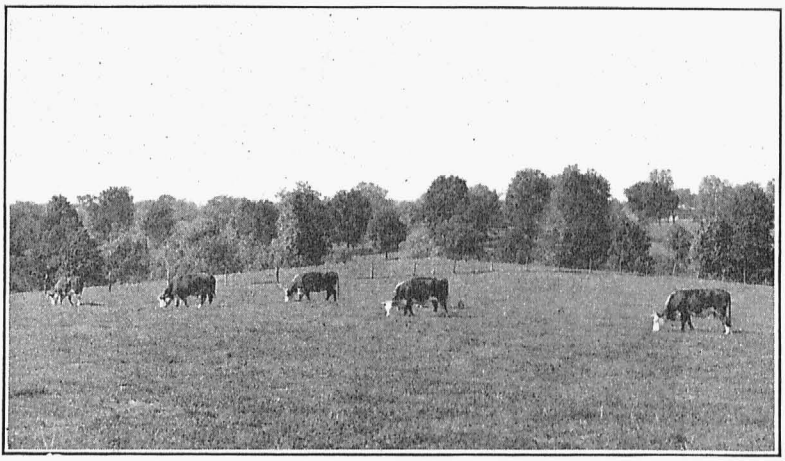
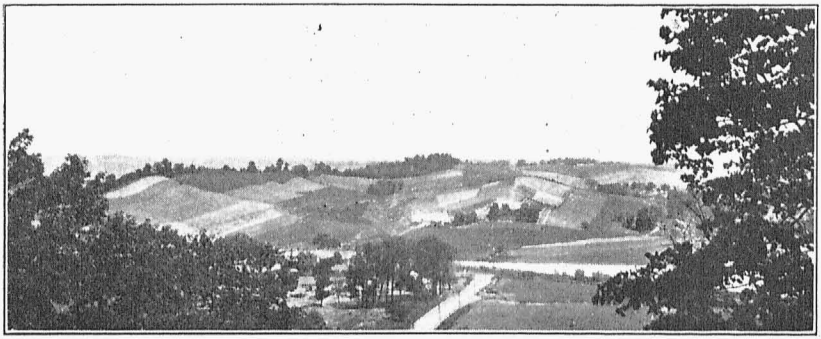


Fig. 13.—Land that is decidedly rolling should be kept in permanent pasture. Sod is the best insurance against soil erosion. (Scene here shown is on one of the pastures of the farm of the Missouri College of Agriculture.)

CONTOUR CROPPING

It is often possible on long slopes and particularly when the slope is mainly in one direction to plant different crops in strips crosswise of the slope. This gives strips of small grain or sod crops alternating with plowed land. The sod tends to absorb much of the water and check the rate of flow, thus reducing the erosion from the cultivated areas. In some cases it may be desirable to keep the steep part of a slope in hay or pasture practically all of the time, while only the upper and lower parts of the slope are included in the regular rotation. A glance at figure 14 will illustrate what is meant by contour cropping. The plowing should be done in long, narrow lands across the slope. In planting row crops it is always desirable to run the rows and do the cultivation as nearly crosswise of the slope as possible. This tends to slow down the rate of flow of

the water, reduces its cutting power and allows more of it to be absorbed by the soil. Where the land slopes in several directions in the same field so that contour cropping or plowing is not practical it is often necessary to employ a system of terraces in order to hold the land from severe washing.



Figs. 14 and 15.—These views from Missouri's brown loess area show how the different crops may be arranged in belts across the slopes. This is one of the best methods of farming steep lands with a minimum amount of erosion.

TERRACING

Rolling land that must be kept in cultivated crops a part of the time may be greatly protected from erosion by the use of terraces. In some of the Southern States terracing has been a rather common practice for many years, but it is just beginning to be used in Missouri. As our lands get older and more valuable it becomes more and more necessary to make every effort to reduce the loss of soil fertility by erosion. Terraces may be used to very great advantage in many cases. The broad base or Mangum terrace is the most practical type of terrace for Missouri. These terraces are built by running a line around the hill almost with the contour but giving it a little fall toward one end to be used as an outlet. The terrace is then built by back furrowing around the hill along the line designated. After six or eight furrows have been thrown together

they are ridged up with a V-shaped drag or small road grader until the terrace resembles a graded roadbed. The plowing and dragging should be continued until the terrace is 12 to 15 inches higher than the previous level and 15 to 20 feet wide at the base. Where such terraces are put in, allowing 4 to 5 feet of drop between them, they should serve a most valuable purpose in keeping a hillside from washing. The terraces should be put in if possible when the land is to be seeded to small grain followed by clover or grass. This gives them time to settle thoroughly before the land is again plowed. The terraces should be reworked whenever the land is plowed and care should be taken to prevent the water breaking through them, which may ruin the entire system. When terraces are properly put in and maintained they will serve a very valuable purpose on many of the rolling farms of this state. However, lands with very steep slopes should not be terraced, but kept in grass permanently. (For further information about the construction of terraces write for Missouri Experiment Station Circular 98.)

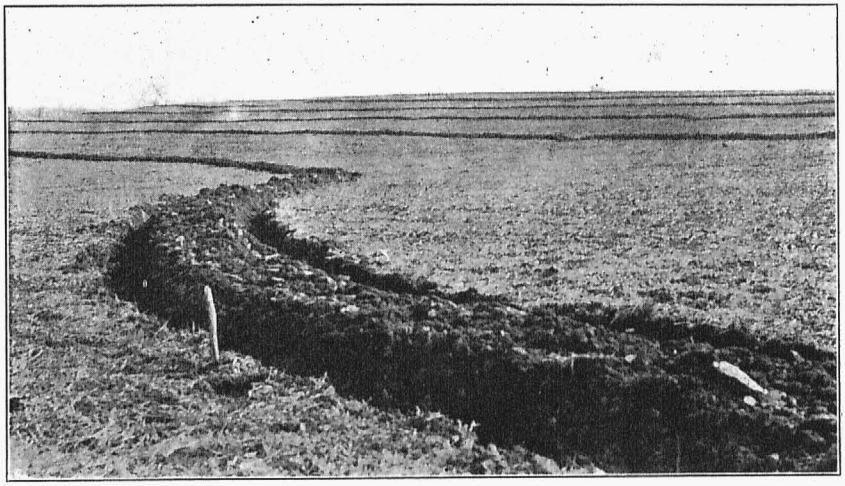


Fig. 16.—A system of Mangum terraces in process of construction. When properly put in and maintained these terraces offer a very effective means of reducing the amount of surface erosion.

HOW TO REJUVENATE ERODED SOILS

Most of the statements so far in this bulletin have had to do with the prevention of erosion. It is also important to consider some things that may be offered as a cure for badly washed or run-down soils. There are some farms that have been allowed to erode to such an extent that it is difficult to grow such crops or use such rotations as have been recommended in the preceding pages. Where this is the case, special methods must be adopted to prevent further depletion of the soil. This may require much time and effort, since building up a worn-out soil is a difficult task and usually requires many years. Many men have purchased worn-out or badly eroded farms with the expectation of building them up in a very short time. This usually results in disappointment. However, it is possible to build up eroded soils and some suggestions here may

be of value to those who are struggling with this problem and at the same time endeavoring to make a living from the farm.

Crop Rotations.—In planning a rotation for eroded land, crops must be chosen that are best adapted to thin soils. The following are suggested as types from which one might work out a system that would suit his own conditions:

1. Soybeans, rye, alsike clover.
2. Kafir, soybeans, wheat, red or alsike clover.
3. Corn or grain sorghum, wheat, red or alsike clover and timothy.
4. Corn, rye, red or alsike clover and red top.
5. Wheat, clover and timothy, timothy and clover.
6. Corn, wheat and sweet clover for pasture and green manure.

Use of Fertilizers.—None of the above rotations can be used with profit on badly eroded soils unless some help is given the crop by means of fertilizers. In most cases the corn or sorghum should have an application of 150 to 200 pounds per acre of a high grade fertilizer such as acid phosphate or a mixed fertilizer such as 2-12-2* or 2-16-2. In the case of very thin soils a 4-12-0 may be the most advisable, since the latter supplies a larger amount of nitrogen.

Small grain crops like wheat or rye should always have fertilizer applied at the time of seeding. Acid phosphate alone may be used on the less eroded fields, while the high grade mixed fertilizers should be used on the thinner lands. The rate of application should be 175 to 200 pounds an acre. This will not only be of value to the wheat or rye but will be of great benefit to the clover or grass crops following.

As a rule no fertilizer should be applied directly to the soybeans or clover crops since these may be used to take out the residual fertilizer left by the grain crops. If mixed hay is left for more than one year it should be top dressed with a light coat of manure or with 150 pounds of a 4-12-0 fertilizer.

Use of Lime.—A large number of eroded soils will also be in need of liming before the best crops of clover can be produced. If only a limited amount of money can be invested in lime each year, a small portion of the farm should be treated and later the treatment may be gradually extended to all parts of the farm. Liming is very beneficial to crops like red and alsike clover, sweet clover, etc. Its effect upon the grain and grass crops is usually less marked, but on many soils will be considerable. When used in conjunction with available phosphates, liming is a profitable practice on the great majority of thin soils.

Use of Manure.—Everyone appreciates the value of manure, but if good applications of fertilizers and lime are used, the amount of manure produced on the farm can be materially increased. It takes large crops to produce large amounts of manure. Fertilizers are the first thing to use to get the large crops on eroded lands, after this, manure may be made to replace some of the fertilizer. When badly run-down soil has been improved somewhat, and larger yields are being produced, the manure may be used principally on corn, while phosphates or mixed fertilizers may be applied to the small grains. The proper combinations of phosphates, manure, and lime are essential steps in bringing up the productivity of run-down land.

Use of Green Manures.—It will be a decided benefit to eroded lands to plow under some green manure occasionally. Of course where the family living must come from the farm, only catch crops or stubble crops can be used for this purpose. That is, if the land has been limed heavily enough that sweet

*Meaning 2 per cent nitrogen, 12 per cent phosphoric acid, and 2 per cent potash.

clover can be grown, the sweet clover may be seeded in wheat and allowed to make some hay or pasture the first fall. The next spring it can be plowed under for corn. It is often possible through the use of phosphates and possibly lime, to get quite a growth of red clover and timothy to plow under if the stubble has not been pastured too heavily. If rye is seeded for pasture it will give some green material to turn under. Its chief benefit, however, is in preventing winter erosion and furnishing early spring pasture.

Fig. 17.—A cover crop of rye may be used as winter pasture, as green manure, and also to protect the soil from winter erosion and leaching.

SUMMARY

1. There are two principal types of soil erosion that affect the upland farms of Missouri. These are sheet or surface erosion and gullying.

2. Gullying may often mar the appearance of a field and seriously interfere with the convenience in cultivation, but surface erosion is probably the greatest source of fertility loss, because it removes a layer of the richest part of the soil from the entire surface. It is only surface erosion that is considered in this bulletin.

3. The principal causes of surface soil erosion are (a) lack of plant growth, (b) steep slopes, (c) heavy rains.

4. Experiments have been conducted at the Missouri Experiment Station in which the amount of soil eroded from land with about an average slope under different conditions of cropping and tillage has been accurately determined.

5. The results of these experiments show that the following number of tons of soil per acre have been lost in a period of six years:

Uncultivated land	207.8
Spaded 4 in. in spring. Cultivated after rains	247.3
Spaded 8 in. in spring. Cultivated after rains	214.2
Bluegrass sod	1.6
Wheat, annually	39.9
Rotation; corn, wheat, clover	13.7
Corn, annually	106.5

6. If farm lands should erode at the foregoing rates it would require approximately the following number of years to erode the top seven inches of soil from land under the various conditions:

Land plowed 4 inches deep	24 years
Uncultivated land left free of weeds	28 years
Land plowed 8 inches deep	29 years
Corn land	56 years
Wheat land	150 years
Rotated land	437 years
Sod land	3547 years

7. Deep plowing did not prove to have as much advantage over shallow plowing for preventing erosion as is commonly assumed.

8. Sod was almost absolute protection against erosion. Small grain crops were quite effective. The loss from corn land was about three times as much as from wheat land.

9. A rotation of corn, wheat, clover allowed only about one-third as much erosion as from wheat land and only about one-eighth as much as from corn land.

10. A good growth of red clover was found to be practically equal to bluegrass sod in preventing surface erosion.

11. The percentage of rainfall lost by surface runoff varied from 48.9 per cent on the uncultivated plot to 11.5 per cent on the sod plot. All the cropped plots took in more water than the plowed land that did not have a crop.

12. Chemical analyses of the eroded material showed that in many cases as much of the mineral plant food elements may be lost through erosion as would be removed from the land by average crops.

13. Crop rotations including sod crops such as clover or mixed hay offer the most practical method of keeping down erosion on rolling land that must be cultivated.

14. Land with more than 15 feet of slope per hundred should usually be kept in permanent pasture.

15. Plowing and cropping crosswise of the slope wherever possible will do much to reduce erosion. Where this cannot be done satisfactorily a system of Mangum terraces should be installed.

16. In the control of surface erosion on Missouri soils there should be combined into a workable scheme all those means that will help solve the problem on a particular farm. In most cases this will involve the use of "soil saving rotations", the judicious use of cover crops, contour cropping and plowing wherever possible, the use of Mangum terraces, and permanent meadows or pastures for very steep lands.

SOIL EROSION PUBLICATIONS

Available from the

Missouri Agricultural Experiment Station

Columbia, Missouri

Bulletin 211.—Controlling Surface Erosion of Farm Lands
.....By F. L. Duley

Research Bulletin 63.—Erosion and Surface Runoff Under Different Soil Conditions (A technical report)
.....By F. L. Duley and M. F. Miller

Circular 98.—The Mangum Terrace
.....By E. W. Lehmann and F. L. Duley

Extension Circular 14.—The Soil Saving Dam
.....By W. H. Baker

A bulletin on methods of filling gullies will appear later.